



## CO Emissions from Gas Engines Fueled by Producer Gas

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IEA/GasNet Meeting Fall 2002

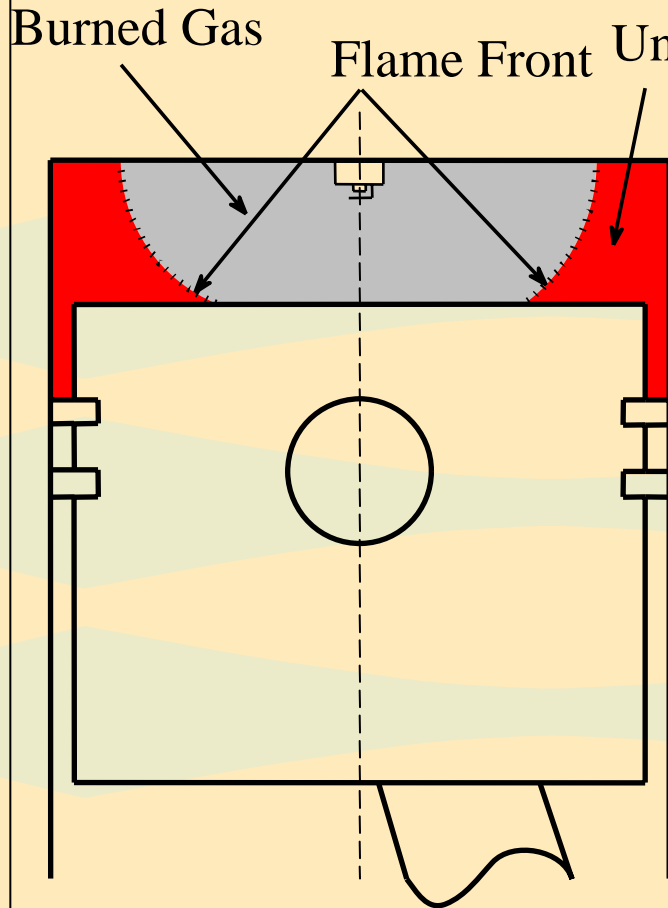
# **CO Emissions from Gas Engines Fueled by Producer Gas**

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# Agenda

- Nature of CO emissions formation in SI gas engines
- Experimental measurements
- Measurements from the Harboøre plant
- CO and global warming
- Conclusion

# CO Emissions Formation from SI Gas Engines



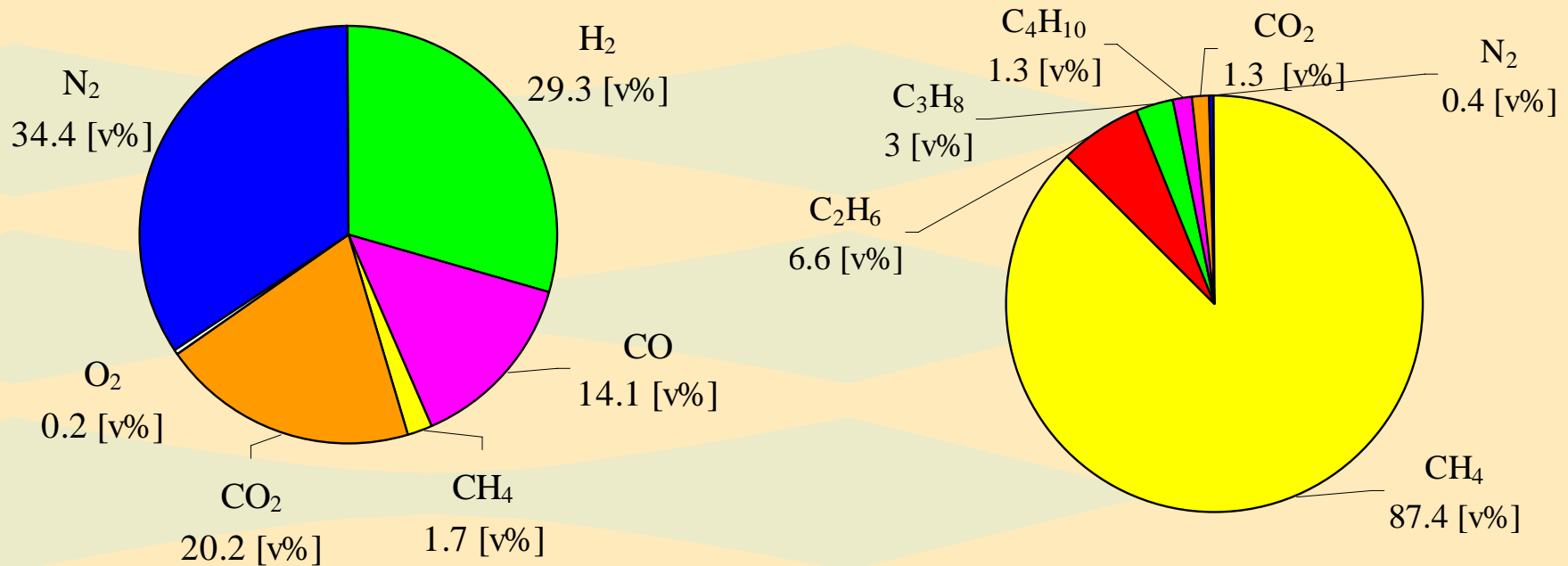
Governing factors:

- Air-fuel ratio ( $\lambda$ )
  - Low combustion-end temperature  $\Rightarrow CO + OH \nrightarrow CO_2 + H$
- Low flame speed  $\Rightarrow$  quenching of the flame  $\Rightarrow$  UHC or UCO
- Stoichiometric air-fuel ratio:  
NG=11:1                      PG=1:1

# Data for Test Engines

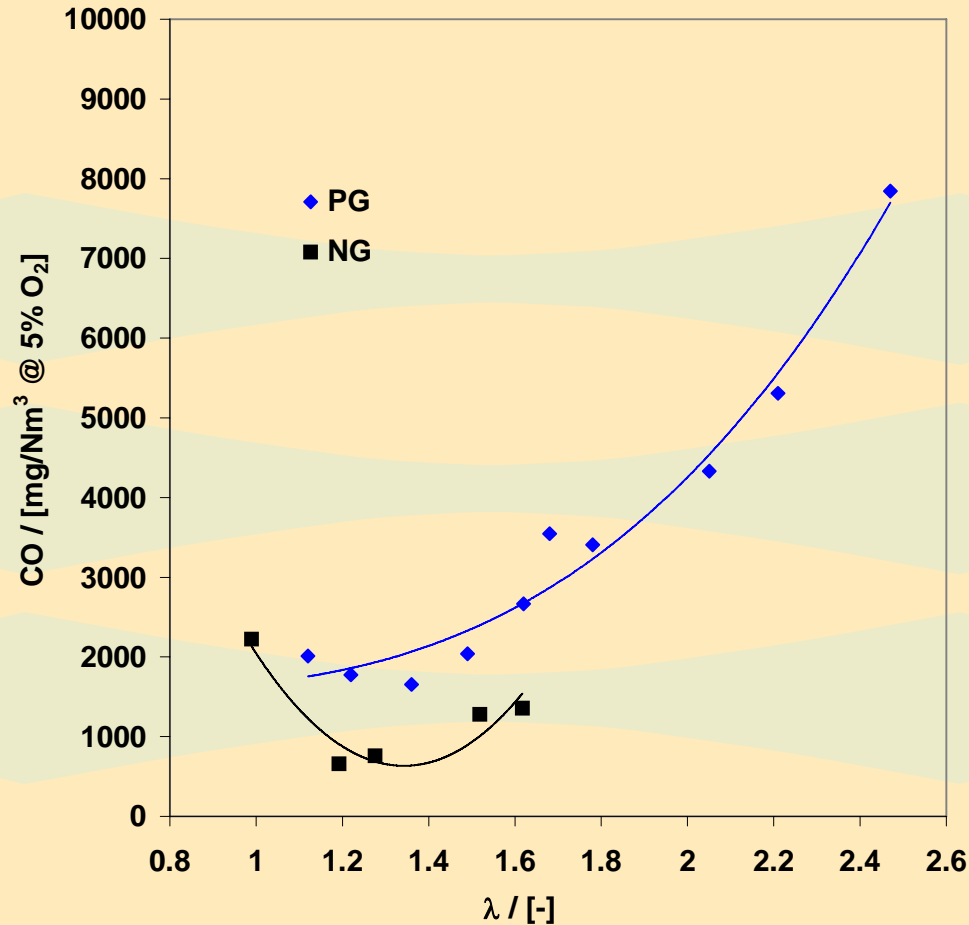
Engine data	BUKH	NISSAN
Bore	85 mm	108 mm
Stroke	85 mm	126 mm
Compression ratio	12:1	12.5:1
Valve per cylinder	2	2
Intake pressure	0.95 bar	0.70 bar
Ignition timing	MBT	-25 deg
Number of cylinders	1	4

# Gas Compositions



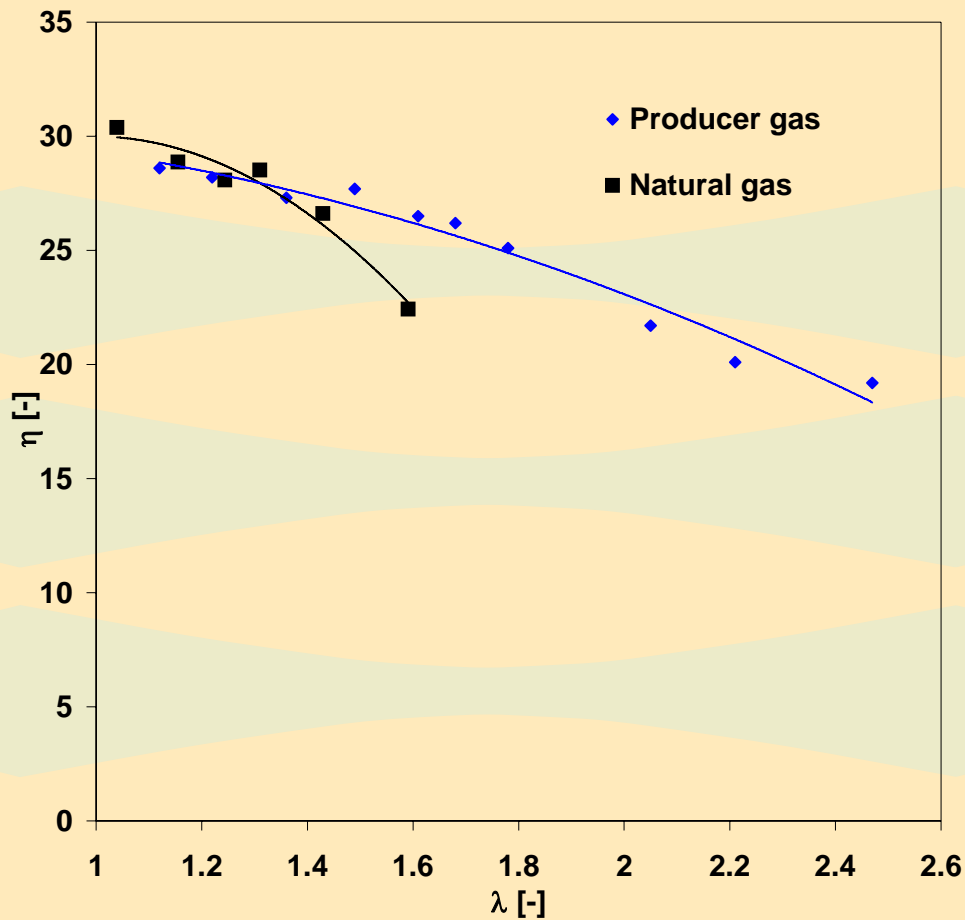
# CO Emissions

(Bukh)



- Strong  $\lambda$  dependency
- Overall high UCO emissions from PG

# Break Efficiency (Bukh)



- Excellent lean burn fuel
- Stable operation for  $1 < \lambda < 3$



# Effect of PG Fuel-CO on CO Emissions

## Fuels:

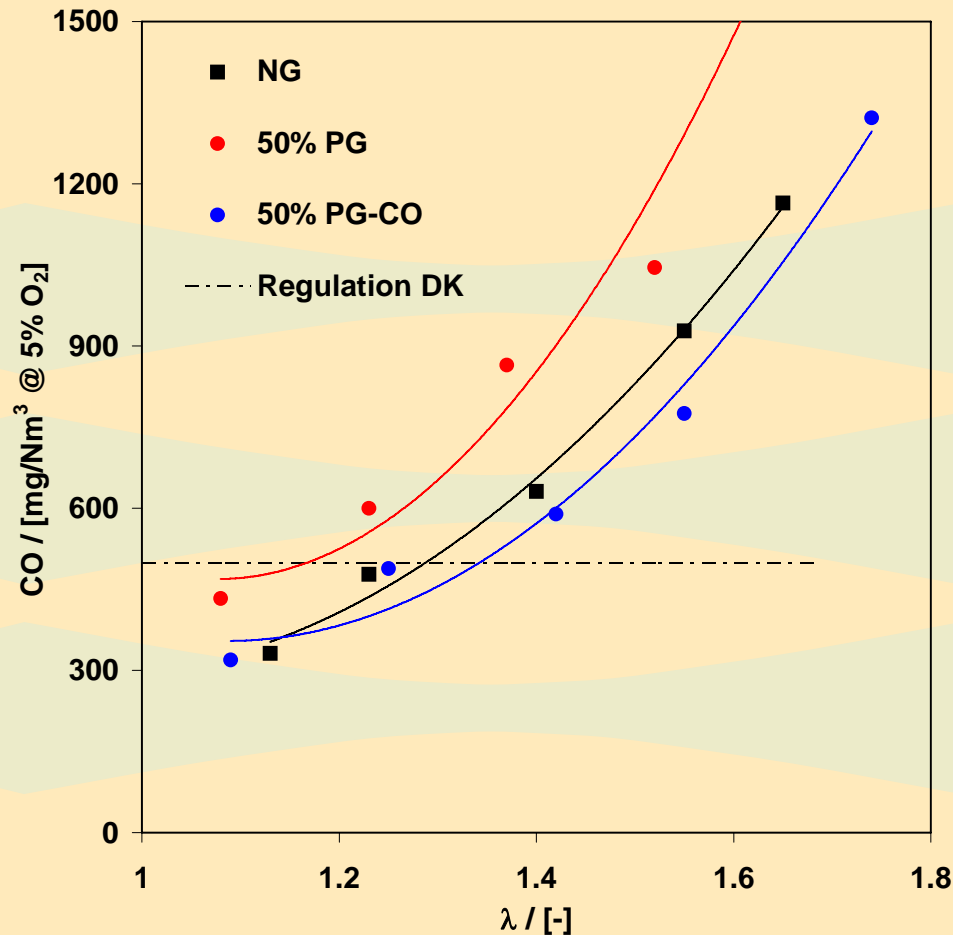
- Natural gas (NG)
- Mixture of 50% Vol. NG and 50% Vol. PG (50% PG)
- Mixture of 50% Vol. NG and 50% Vol. PG where the CO content has been replaced by N<sub>2</sub> (50% PG-CO).

## Measurements:

- CO emission
- UHC emission

# CO Emissions

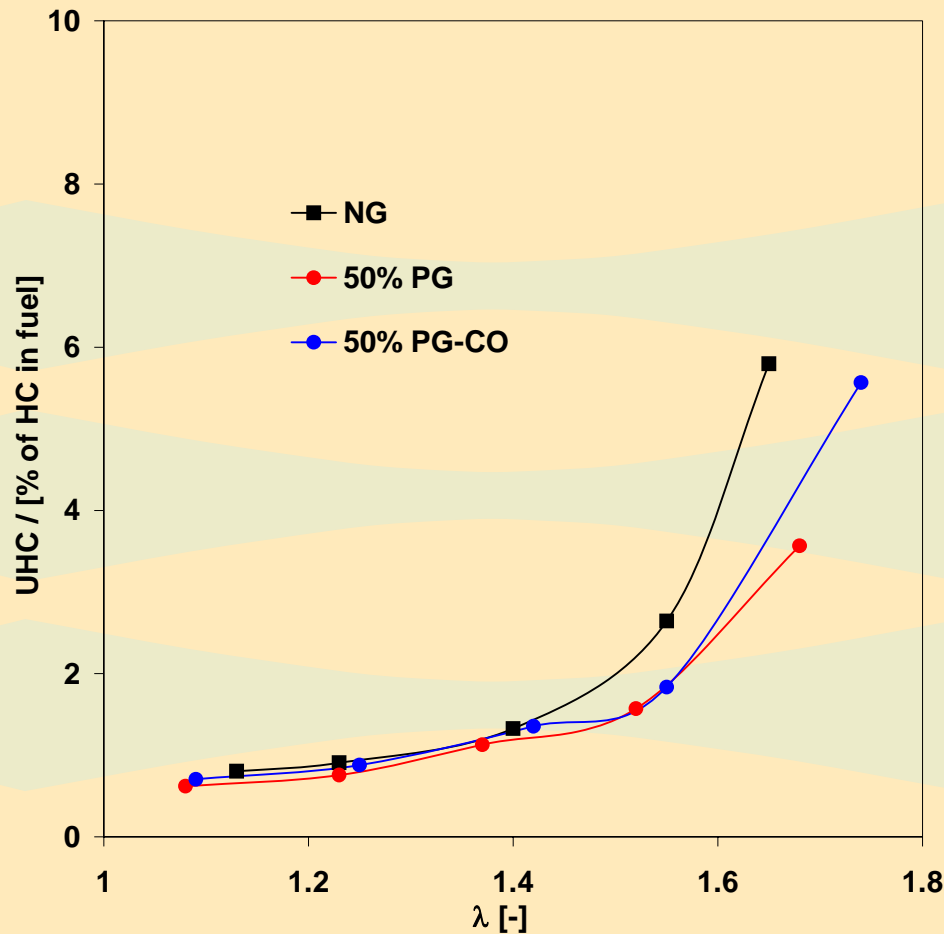
## (Nissan)



- Up to 30% higher CO emissions when fueled by 50% PG compared to NG.
- Reduction in emissions when fuel-CO is replaced by N<sub>2</sub>.
- Difference due to UCO

# UHC Emissions

## (Nissan)



- Addition of producer gas increases combustion efficiency at lean conditions.
- CO content has no significant influence on combustion efficiency.
- For  $\lambda > 1.6$  there is an reduction in UHC emissions of more than 50% compared to NG

# Measurements from the Harboøre Plant

PAH [ $\mu\text{g}/\text{Nm}^3$ , dry]	Before ESP	After ESP	After Engine
Naphthalene	37,000	6,300	4.7
Phenanthrene	9,800	<18	1
Benzo(a)pyrene	500	<35	<0.12
TOTAL PAH	68,000-70,000	6,600-6,800	6.4-7.1

$\lambda$	CO (Before)	CO (After)	Reduction
[-]	[ppm]	[ppm]	[%]
2	1,717	413	76

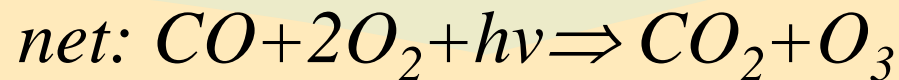
- High CO emissions
- Very low PAH emissions
- Catalytic reduction possible

Measurements of PAH and CO emissions for engine #1 at the Harboøre gasification plant in Denmark. Data from Babcock & Wilcox

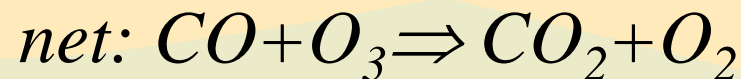
Vølund R&D Centre - august 2001.

# CO and Global Warming

- CO leads to photochemical production of ozone in the presence of high  $\text{NO}_x$  concentrations



- For low  $\text{NO}_x$  concentrations CO leads to ozone destruction



- $\text{O}_3$  has about the same global warming potential (GWP) as  $\text{CH}_4$

# Conclusion

- The high CO emissions from engines fueled by producer gas are mainly due to unburned fuel-CO (UCO)
- Combustion efficiency is not influenced by fuel-CO
- High CO emissions do not equal high PAH emissions
- UCO emissions from producer gas engines are comparable to UHC emissions from natural gas engines, both in origin and in GWP
- Separate emissions standards are needed for producer gas engines both for CO and PAH emissions

# Questions ???

## Wood Gas



## The Green Engine Fuel for CHP

# Contact Information

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# Mass Fraction of Fuel Burned (Nissan)

